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A STUDY OF PHOTOSTRESS AND FLASH BLINDNESS

TECHNICAL DOCUMENTARY REPORT NO. SAM-TDR-62-144

December 1962

USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas

Task No. 775101

USAF School of Aerospace Medicine, Brooks AF Base, Tex.

SAM-TDR-62-144. A STUDY OF PHOTOSTRESS AND FLASH BLINDNESS. Dec. 62, 6 pp. incl. illus., tables, 4 refs.

Unclassified Report

An experiment was designed to study the effects of pupillary size, flash intensity, testing patch luminance, and subject variability following photostress testing with intense light flashes. Fifteen subjects were exposed to illuminations ranging from 86,080 lux to 242,100 lux as measured at the corneal plane.

1. Ophthalmology
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FOREWORD

This report was prepared by the following personnel of the Ophthalmology Department:

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The authors express appreciation to the subjects who volunteered for these studies; to A2C Bernard R. Robinson and to Mrs. Bertha B. Secord for their contributions to the completion of this work; and to Alton J. Rahe, of the Biometrics Department, for his handling of the statistical analyses and his penetrating review of the paper.

ABSTRACT

An experiment was designed to study the effects of pupillary size, flash intensity, testing patch luminance, and subject variability following photostress testing with intense light flashes. Fifteen subjects were exposed to illuminations ranging from 86,080 lux to 242,100 lux as measured at the corneal plane. Recovery was measured as the period of time required after dazzle to regain sufficient visual function to perceive a threshold discriminatory task. The experimental results are discussed and the operational significance is implied.

This technical documentary report has been reviewed and is approved.

ROBERT B. PAYNE
Colonel, USAF, MSC
Chief, Operations Division

A STUDY OF PHOTOSTRESS AND FLASH BLINDNESS

1. INTRODUCTION

The hazard of flash blindness to the success of an aerospace mission is well recognized. Previous reports from this laboratory have described a photostress test[1] that has been developed to evaluate the problem (3). This paper presents the results of an experiment designed to study more comprehensively the nature of the recovery from severe dazzle.

2. SUMMARY

Results are reported of a study designed to evaluate the problem of flash blindness. Fifteen subjects were exposed to light flashes ranging over three levels of corneal illuminance: 86,080 lux, 150,640 lux, and 242,100 lux, using two different pupil conditions and two testing luminances. Analysis of the results demonstrates that:

1. A linear plot describes the relationship between time required for recovery and flash intensity over the range tested.

2. There is a significant difference in recovery rate between subjects. This variation is demonstrated by an actual change in the slope of the recovery function.

3. Pupillary size has a significant effect upon the time required for recovery from dazzle.

The operational significance of these observations is implied.

Received for publication on 26 September 1962.

[1]Photostress as used here refers to the delivery of light energy to the retina. Flash blindness refers to the resultant visual effect.

3. METHODS AND MATERIALS

The basic technic utilized in this work has been previously described (3). The fundamental components of the instrumentation are a Meyer-Schwickerath Zeiss light coagulator and a Goldman-Weekers adaptometer. The coagulator was modified by using a solid shutter to prevent emission of light except during test flashes and by using a −10.00 diopter lens to diverge and reduce the intensity of the beam. A diffusion screen was interposed between the coagulator and the subject to prevent point focus of the beam by the observer's eye. For this experiment test flashes of 150 msec. that illuminated the cornea with one of three illuminances were used. Two recovery functions were tested on the Goldman-Weekers adaptometer. One was the time required to regain the ability to discriminate the presence of a 0.06 ft.-L. light flashing on and off at 1-second intervals and the other was the time required to discriminate the presence of the same light when the intensity was reduced to 0.013 ft.-L. It was found experimentally that the ability to recognize the contrast of the brighter testing luminance corresponded approximately with the ability to read normally red-lighted aircraft instruments. Precise measurements of recovery were made on timing clocks that were automatically started when the shutter opened to produce the light flash and were stopped by the subject when he saw the appropriate testing stimulus.

4. SUBJECTS

Fifteen subjects were used in this experiment. The group consisted of volunteer members of the permanent-duty personnel of the USAF School of Aerospace Medicine. Ages ranged from 23 to 42 years. Two of the group

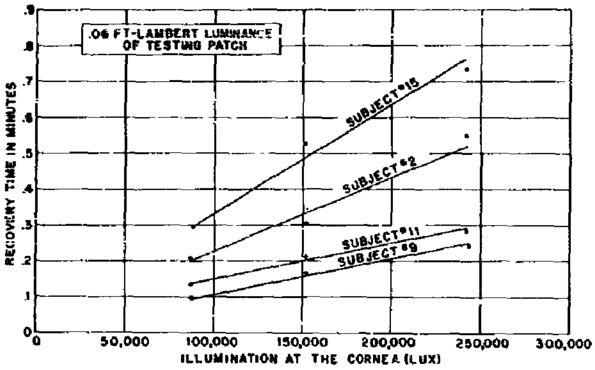

FIGURE 1

Luminance (0.06 ft.-L.) of testing patch.

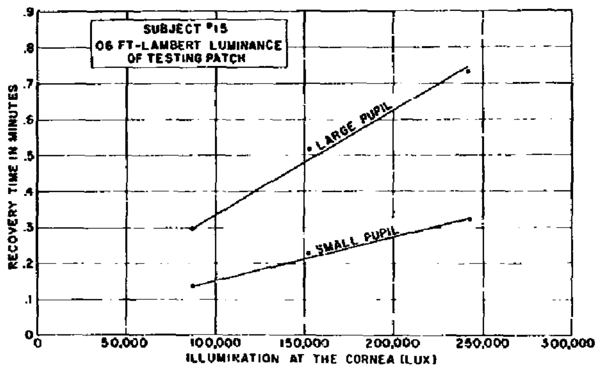

FIGURE 2

Subject 15—0.06 ft.-L. luminance of testing patch.

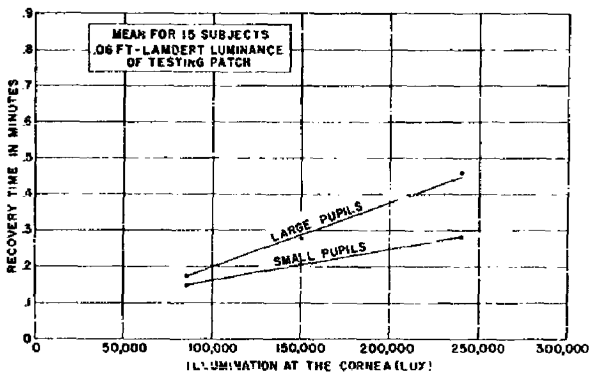

FIGURE 3

Mean for 15 subjects—0.06 ft.-L. luminance of testing patch.

were Negroes and one was Indian. All subjects were given a comprehensive ophthalmologic evaluation including central fields and slit lamp examination before and after testing. All subjects had a visual acuity of 20/20 or better.

5. PROCEDURE

The experiment was designed so that the effects of pupillary size, flash intensity, testing patch luminance, and intersubject and intra-subject variability upon foveal function could be studied. All testing was monocular, using the right eye. With this design each subject was observed at four appearances, two of which were with a dilated pupil and two with a constricted pupil. The pupil size for each appearance was randomly determined, subject to the above conditions. During each appearance the subject was exposed to 2 flashes at each of three illuminances: 86,080 lux, 150,640 lux, and 242,100 lux as measured at the corneal plane. Each flash lasted 150 msec. The sequence of presentation of the 6 flashes was randomized. The subject had no prior information about the flash sequence.

Before testing, the pupillary size of the subject's right eye was controlled by pretreatment with either a 1 % pilocarpine or a 10 % phenylephrine solution. When the desired effect had been produced, the pupil was measured and its size recorded. The subject was then preadapted 10 minutes in a dark room and positioned with his eye centered before the diffusion screen. After the positioning had been checked, the flash was triggered and simultaneously the timing clocks were started. The subject then turned toward the Goldman-Weekers adaptometer. Initially, no form was perceivable through the intense scotoma that had been induced, but as the scotoma dimmed, the blinking test pattern became apparent through the afterimage. When he could discriminate 2 flashes of the 0.06 ft.-L. testing patch, the subject pressed a switch stopping the first timing clock. He continued to view the target area until he could discriminate the contrast of 2 flashes of the 0.013 ft.-L. testing patch and then again pressed the switch stopping another timing clock.

6. RESULTS

Analyses of variance were performed on the data. These analyses indicated that a linear relationship between recovery time and flash intensity gives a satisfactory description of the results over this range of intensities; however, the best fitting lines differ in slope, depending upon the subject and the pupil size. The slopes vary from subject to subject and the slope of the best fitting line is greater for the large pupil than for the small pupil. This is true for both the 0.06 ft.–L. testing patch and for the 0.013 ft.–L. testing patch (see tables IV and VIII).

Three representative figures are presented to illustrate these points. The figures have been derived by plotting the time required to regain visual discrimination to perceive the 0.06 ft.–L. testing patch as a function of flash illumination at the eye, and then by drawing the best fitting straight line.

In figure 1 the results of the testing of 4 subjects are plotted. Each point represents the mean of 4 measurements taken at that intensity when the pupil had been dilated. Note the difference in recovery rate between subjects.

Figure 2 is a plot of the complete results of testing subject 15. Each point represents 4 measurements made at that intensity. This graph demonstrates a change in recovery rate produced by altering the size of the pupil.

Figure 3 is a graph plotting the mean recovery times for all 15 subjects tested in the experiment. Each point represents the mean of 60 exposures at that intensity. The upper line is the mean recovery rate for the mydriatic testing. The lower is the mean recovery rate for the miotic testing. The mean recovery times and pupillary sizes will be found in table III.

The data is presented in its entirety in tables I to VIII. For ease of reading it has been subdivided into the results with the 0.06 ft.–L. testing patch and the results with the 0.013 ft.–L. testing patch.

TABLE I

Subject x intensity means (expressed in thousandths of a minute) for the large pupil testing patch brightness 0.06 ft.–L.*

Subject	Mean pupil size (mm.)	Intensity		
		86,080 lux	150,640 lux	242,100 lux
1	8.00	.1800	.3063	.5113
2	7.75	.2088	.3050	.5013
3	8.25	.2113	.3550	.6313
4	7.75	.2088	.2688	.4750
5	7.75	.2050	.2913	.4675
6	6.00	.1763	.2738	.6400
7	6.50	.1200	.1838	.3088
8	6.50	.1425	.2688	.4175
9	5.75	.0963	.1663	.2400
10	8.25	.1488	.2863	.5550
11	7.00	.1363	.2113	.2838
12	8.75	.1213	.2075	.3338
13	7.00	.1638	.2613	.4188
14	8.75	.1900	.2488	.3800
15	7.50	.2950	.5288	.7350

*Figures in columns represent the mean of four exposures at that intensity.

TABLE II

Subject x intensity means (expressed in thousandths of a minute) for the small pupil testing patch brightness 0.06 ft.–L.*

Subject	Mean pupil size (mm.)	Intensity		
		86,080 lux	150,640 lux	242,100 lux
1	2.00	.1475	.2025	.2488
2	1.50	.2025	.2088	.2563
3	3.50	.1125	.2488	.3988
4	3.00	.1913	.2413	.3350
5	2.00	.1625	.2075	.2788
6	2.25	.1563	.2238	.4025
7	2.25	.1138	.1475	.2000
8	1.75	.2050	.2850	.3575
9	1.00	.1025	.1450	.1650
10	2.50	.1613	.2425	.4463
11	3.00	.1038	.1350	.1575
12	2.00	.1513	.1438	.1950
13	2.00	.1413	.1838	.2325
14	2.50	.1363	.1813	.2250
15	1.75	.1375	.2275	.3225

*Figures in columns represent the mean of four exposures at that intensity.

TABLE III

*Pupil x intensity recovery time means (expressed in thousandths of a minute) for testing patch brightness 0.06 ft.–L.**

Pupil	Mean pupil size (mm.)	Intensity		
		86,080 lux	150,640 lux	242,100 lux
Small	2.15	.148	.205	.281
Large	7.62	.174	.278	.460

*Figures in columns represent the mean of 60 exposures at that intensity. The numbers are the mean values for 15 subjects tested in the experiment.

TABLE IV

Analysis of variance on original data for testing patch brightness 0.06 ft.–L.

Source	d.f.	S. Sq.	M. Sq.	F	P
Subject	14	1.350194	.096442	7.13	< .001
Pupil	1	.782134	.782134	28.36	< .001
Pupil x subject	14	.386136	.02758	2.04	= .05
Sitting/pupil/subject	30	.405631	.013521	5.12	< .001
Intensity	2	2.693868	1.346934	73.78	< .001
Linear	1	2.688556	2.688556	80.05	< .001
Deviation	1	.005312	.005312	1.82	N.S.
Subject x intensity	28	.511136	.018255	6.91	< .001
Linear	14	.470194	.033585	12.72	< .001
Deviation	14	.040942	.002924	1.10	N.S.
Pupil x intensity	2	.365760	.182880	88.35	< .001
Linear	1	.362537	.362537	137.32	< .001
Deviation	1	.003223	.003223	1.22	N.S.
Pupil x subject x intensity	28	.057849	0.00207	0.78	N.S.
Sitting/pupil/subject x intensity	60	0.158321	.00264	2.03	< .001
Duplicate/sitting/pupil/intensity/subject	180	.233801	.001299		
Total	359	6.944829			

TABLE V

Subject x intensity means (expressed in thousandths of a minute) for the large pupil testing patch brightness 0.013 ft.–L.*

Subject	Mean pupil size (mm.)	Intensity		
		86,080 lux	150,640 lux	242,100 lux
1	8.00	.2575	.4675	.7088
2	7.75	.3825	.4475	.6650
3	8.25	.4450	.6663	1.0325
4	7.75	.2675	.3338	.7475
5	7.75	.3238	.5363	.7725
6	6.00	.2575	.3938	.8750
7	6.50	.2175	.3988	.5613
8	6.50	.2175	.3838	.5763
9	5.75	.1550	.2600	.4213
10	8.25	.3038	.4888	.7975
11	7.00	.2350	.3175	.4175
12	8.75	.1938	.3875	.5838
13	7.00	.3300	.5875	1.0138
14	8.75	.2975	.5288	.8125
15	7.50	.5575	.7813	1.1350

*Figures in columns represent the mean of four exposures at that intensity.

TABLE VI

Subject x intensity means (expressed in thousandths of a minute) for the small pupil testing patch brightness 0.013 ft.–L.*

Subject	Mean pupil size (mm.)	Intensity		
		86,080 lux	150,640 lux	242,100 lux
1	2.00	.3288	.4500	.5988
2	1.50	.2950	.3200	.4375
3	3.50	.1763	.5150	.7263
4	3.00	.3988	.4225	.7725
5	2.00	.4050	.5288	.5513
6	2.25	.3075	.4888	.6475
7	2.25	.3313	.4300	.5450
8	1.75	.3638	.5250	.5738
9	1.00	.2800	.3113	.4125
10	2.50	.4638	.7325	1.1038
11	3.00	.2100	.2538	.2688
12	2.00	.3088	.3363	.4350
13	2.00	.4000	.4813	.6825
14	2.50	.4238	.7188	.8338
15	1.75	.2688	.4300	.5725

*Figures in columns represent the mean of four exposures at that intensity.

TABLE VII

*Pupil x intensity recovery time means (expressed in thousandths of a minute) for testing patch brightness 0.013 ft.–L.**

Pupil	Mean pupil size (mm.)	Intensity		
		86,080 lux	150,640 lux	242,100 lux
Small	2.50	.331	.463	.613
Large	7.62	.296	.465	.741

*Figures in columns represent the mean of 60 exposures at that intensity. The numbers are the mean values for 15 subjects tested in the experiment.

TABLE VIII

Analysis of variance on original data for testing patch brightness 0.013 ft.–L.

Source	d.f.	S. Sq.	M. Sq.	F	P
Subject	14	4.273011	.305215	4.16	$< .005$
Pupil	1	.096531	.096531	0.66	N.S.
Pupil x subject	14	2.039171	.145655	1.98	$< .10$
Sitting/pupil/subject	30	2.202081	.073402	4.76	$< .001$
Intensity	2	7.964947	3.982473	87.66	$< .001$
Linear	1	7.964917	7.964917	102.40	$< .001$
Quadratic	1	.000030	0.0000300	0.002	N.S.
Subject x intensity	28	1.272054	.045430	2.95	$< .001$
Linear	14	1.088959	0.077782	5.05	$< .005$
Deviation	14	0.183095	0.013078	0.85	N.S.
Pupil x intensity	2	0.451246	.225623	20.75	$< .001$
Linear	1	.431746	.431746	39.72	$< .001$
Deviation	1	.019500	.019500	1.79	N.S.
Pupil x subject x intensity	28	.304411	.010871	0.71	N.S.
Sitting/pupil/subject/intensity	60	.924476	.015407	1.92	$< .001$
Duplicate/sitting/pupil/subject/intensity	180	1.445912	.008032		
Total	359	20.973840			

7. DISCUSSION

This report presents information that has been acquired from an experiment designed to investigate the parameters of the phenomenon of flash blindness. The experimental results are presented in detail. The discussion will be concerned only with the portion of the data that is pertinent to aerospace problems and with inferences that might be made from this data.

One of the experimental objectives was to study how recovery of visual discrimination is related to the intensity of the dazzling flash, since it was felt that determination of the recovery rate would enable the investigators to make predictions about the duration of flash blindness in operational situations. Analysis of the data indicates the relationship is linear for the range of intensities investigated. This is true for both dilated and constricted pupils (see tables IV and VIII).

The results also indicate that there is a highly significant difference in the recovery rates between subjects (see tables IV and VIII). Figure 1 illustrates the fact that a linear slope can be plotted that represents a subject's rate of recovery over the intensity range tested and that this rate varies from individual to individual. The explanation of this variation is unknown and will require elucidation of the mechanism of the physiologic response to dazzle; however, the individuality of the responses implies that healthy subjects show considerable differences in their ability to handle the sensory overload of a photostress of this magnitude.

An example of the significance of this variation is the fact that 2 normal subjects may differ by as much as 30 seconds in their recovery from a dazzling flash of 242,100 lux. Encounters with light fields of this intensity may occur in nuclear operations, and a time difference of this magnitude for recovery could be of operational significance in missions where rapid visual recovery from dazzle is necessary.

The data also demonstrates that pupillary size has a significant effect upon the severity of the dazzling experience (tables III, IV, VII, VIII). Inducing miosis before photostress testing decreased the time required to regain visual discrimination as compared to the results with a mydriatic pupil. The magnitude of the effect varied from individual to individual and was greater with the brighter testing patch than with the duller one. In many instances the time required for recovery was shortened by as much as 50% by inducing miosis.

A function of the pupil is to serve as a variable diaphragm regulating the amount of energy incident upon the retina. The effect of decreasing the size of the pupil before photostress testing may be likened to placing a neutral density filter before the eye, since both diminish the retinal irradiance from such exposure and thus decrease the severity of the dazzle.

The next consideration is the application of the information derived from this work to problems in space and nuclear operations. It is extremely difficult to extrapolate from a carefully controlled laboratory situation to a field situation where a number of additional factors such as point of fixation, atmospheric conditions, and weapon characteristics must be considered. If the limitations incidental to hypothesizing from laboratory experience are considered, it is possible to make several statements.

It has been established in a number of laboratories that the duration of the relative scotoma following dazzle is related to the intensity of the dazzle and the luminance of the visual task to be performed (1–4). The exact nature of the relationship of flash intensity to recovery has not been clarified; in our experience, however, for a range of corneal illuminance of 86,000 to 242,000 lux, it is linear.

In many instances it will be possible to predict the duration of visual embarrassment that will attend encounter with intense light fields in an operational situation if details of the nature of the photostress are supplied; however, if these estimates are to be made, it will probably be necessary to derive a baseline on the men who will be involved in order to establish their recovery rate, since individual variability is so great that general predictions will not be reliable. These estimations should probably be made only for retinal illuminances that will allow interpolation from the experimental data. A linear extrapolation to more intense flashes may not be accurate, since the recovery rate will change as the retinal burn threshold is approached.

Finally, although many protective devices are under development, there is no reliable method to prevent flash blindness from nuclear operations. This experiment demonstrates the effect of drug-induced miosis in decreasing the time required to recover from photostress. The protection offered by pilocarpine miosis is only relative but in many situations it may be adequate. The possibility of such a simple means of protection deserves further investigation.

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